TOWARDS A STRATEGIC ANALYSIS SYSTEM OF THE BLACK SPOTS IN THE ROAD TRAFFIC

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Analiza siguranţei circulaţiei rutiere arată că, deşi există numeroase metode, modele şi baze de date statistice care se referă la diferite aspecte ale circulaţiei, acestea nu sunt tratate într-o concepţie sistemică, integrată, ci sunt utilizate în mod independent. Din acest motiv, cercetarea efectuată a dus la concluzia că trebuie constituit un sistem de analiză şi asistare a deciziilor în domeniul siguranţei rutiere, cu particularizare la identificarea şi tratarea punctelor negre din perspectiva abordării cu prioritate a situaţiilor critice legate de siguranţa circulaţiei.

The road traffic safety analysis shows that, although there are numerous methods, models and statistic databases referring to various traffic aspects, they are not dealt with in a systemic and integrated way, but independently. For this reason, the research conducted has led to the conclusion that a system for the analysis and assistance of the decisions in the road safety field must be set up, especially for identifying and treating the black spots from the perspective of the approach of critical situations related to traffic safety.

Keywords: road safety, black spots

1. Introduction

The freight and passenger road transports of Romania dominate over the other transport modes, figure 1.1, due to their flexibility and possibilities of providing door-to-door services, which will continue on the future. Without an effective road transport system, the other transport modes cannot operate in the intermodal transport technologies. As a result of the increasing demands of the passenger and freight carriers, of the enhancement of the car park and of the modernization of roads, especially national roads, an ascending evolution of the road traffic on the public road network takes place, which also generates road safety problems.

It is found that, although there are numerous methods, models and statistic databases referring to many and different aspects regarding traffic safety, they are not dealt with in a systemic and integrated way, being independently used.

Even from the institutional point of view, those applications are managed or used by various organizations which do not co-operate, although they show professionalism and reliability in the sequence they are processing, and if they do

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so, this happens in organizational forms of facultative and optional nature. To this effect, the accidents issue is dealt with well enough, but the results barely generate the effects at the global level of the road safety. For this reason, it is necessary to set up an integrated system for identifying and treating the black spots from the perspective of the road transport safety in Romania.

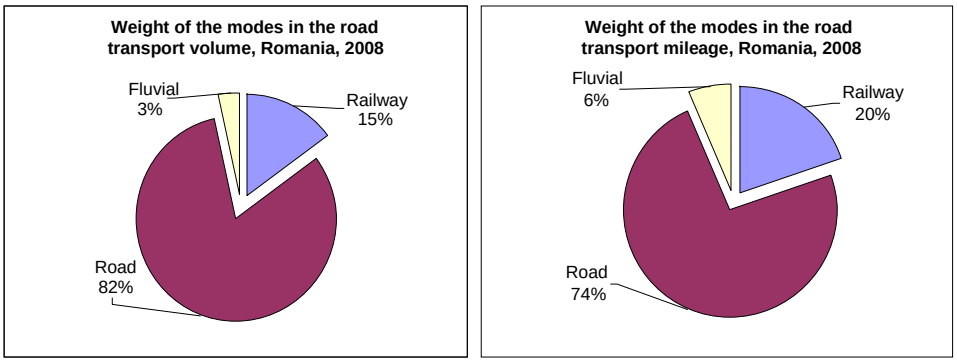

Fig. 1.1 Weight of transport modes in Romania, 2008
(Data source: INS [1])

2. External costs due to road accidents

The costs can be categorized as internal or external, fixed or variable, direct or indirect, specific or not to a certain situation, according to the way in which the cost affects the individual or common decisions [2]. The externalities including the road accident consequences occur when the activity of an agent does not exclusively depend on the variables they control, but on a number of variables which are not within the field of their decisional activity.

The consumers seem to be more affected by the internal, variable and short-term costs, and the authorities are concerned with the external cost analysis.

The difficulty of quantifying the external effects is mainly due to the fact that there are numerous variable aspects depending on the factors that cannot be measured in certain specific conditions. The currently used calculation methodologies are very different, and the comparison of the obtained results does not always provide the possibility of adopting any common conclusions. In some countries, they have tried the monetary assessment of the external costs relating to road transports, estimating a major size of them, even bigger than the one the proper activity has in the GDP (gross domestic product) formation. Even though there is now a high degree of incertitude related to the assessment of the external costs specific to transports, the influences that the transport activity has on the environmental factors and on the health level is a generally accepted truth.

The size and incidence of these influences is variable depending on certain characteristics of the transport process: transport mode, vehicle type and age,

period and route of movement, weather conditions, infrastructure status, traffic intensity, driving style, type of fuels used, energy efficiency of vehicle etc.

There are still a few disputes on how much of that cost is external cost, due to the fact that the car driver assigns a risk degree to the other traffic participants only when the possibility of collision occurs. The concept of cost due to accidents is complex, because of the occurrence of some ethical problems such as the monetary assessment of human life. It is considered that the costs triggered by the production decrease must be also added to the medical, administrative and salary costs related to car accidents.

The probability for a vehicle to collide with another one, on the travelled kilometre, increases linearly by the traffic intensity, and the total number of accidents is the product between the risk per kilometre travelled by a vehicle and the traffic intensity. If the road users do not adapt their driving style once with the risk degree increase by the traffic intensification, the total number of collisions is likely to increase by the traffic intensity square, and the total number of accidents will linearly increase by the traffic. The individuals adapt their driving style depending on the traffic intensity. The number of collisions per kilometre increases, but the accident rate decreases. For small and medium traffic volumes, the marginal rate of accidents is under the average rate, having a ratio between them within the interval of 40-60% in case of motorways and interurban roads.

The research in the field provides results converging to several major problems:

- The activity and technical condition of the vehicles are major sources of external costs;
- The road infrastructure is represented by areas of major risk for traffic participants' life and health. The risk is associated to accidents caused during the car traffic.

3. Ranked analysis of the road safety with a view to identify and treat the black spots

The analysis system we consider is of hierarchical type and contains the blocks: investigation and analysis of an accident or of a road sector, territorial analysis of the distribution and characteristics of the major accidents, assistance of decision-makers in the elaboration of strategies, measures and projects for the prevention and treatment of critical points.

There are two approaches of the problem:

- **Top-down** approach, through which the black spots are identified and the rectification measures and strategies are developed.
- **Bottom –up** approach, through which data on accidents are collected, information are produced by processing these data, the databases are updated, the methods and models of the road safety system are improved.

3.1 Distribution of black spots on the Romanian roads

The graph in figure 3.1, drawn up based on the data in table 3.1 (Data source: M.A.I.), shows that the black spots, as well as the respective fatalities and accidents are dominant on about 8-10 roads. This information is useful in the preparation of a detailed strategy for the reduction of the black spots on those roads, which will be reflected on how the available resources are allocated.

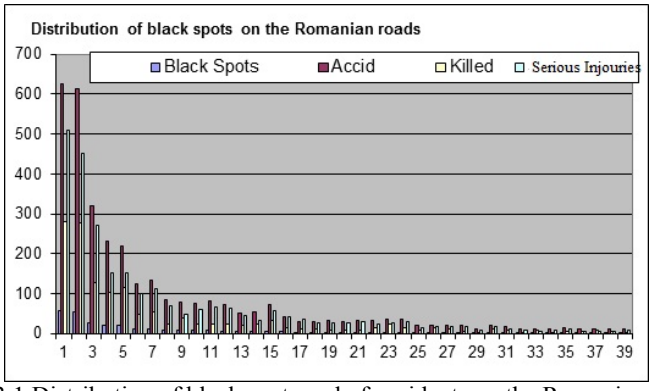

Fig. 3.1 Distribution of black spots and of accidents on the Romanian roads

3.2 Characterization of road safety on a certain road

To illustrate, we start from the relative frequencies of the car accidents incidence with the county sectors of DN1 that can be assimilated with the probabilities p_{ij} for the accidents from i causes to happen in DN1 sectors which transit the counties j, table 3.2.

The probability p_i for an accident on DN1 to be generated by the cause i, i=1,…,m, it is obtained as well as the probability p_j for an accident on DN1 to happen in the county j, j=1,…,n.

The graphical representation of these probabilities generates new qualitative information that contribute to reveal the accidental aspects of the traffic along the analyzed road.

Table 3.1

Distribution of black spots and of accidents on the Romanian roads

i	Road	Blackspots	NoAccid	NoKilled	NoSI
1	DN1	57	625	279	511
2	DN2	55	613	276	450
3	DN7	26	319	127	271
4	DN15	21	232	103	152
5	DN2A	21	219	116	153
6	DN13	12	125	48	101
7	DN6	11	133	55	111
8	DN5	8	84	25	69

9	**DN28**	**7**	**77**	**39**	**49**
10	**DN3**	**7**	**74**	**25**	**60**
11	**DN39**	**7**	**81**	**24**	**66**
12	**DN73**	**6**	**72**	**24**	**64**
13	**DN13A**	**5**	**52**	**19**	**45**
14	**DN25**	**5**	**55**	**24**	**34**
15	**DN65**	**5**	**71**	**32**	**57**
16	**DN1C**	**4**	**42**	**13**	**41**
17	**DN11**	**3**	**31**	**12**	**36**
18	**DN12A**	**3**	**31**	**10**	**27**
19	**DN18**	**3**	**33**	**7**	**27**
20	**DN1B**	**3**	**31**	**8**	**27**
21	**DN4**	**3**	**32**	**7**	**29**
22	**DN67**	**3**	**32**	**15**	**24**
23	**DN79**	**3**	**35**	**24**	**26**
24	**DN7C**	**3**	**36**	**15**	**30**
25	**DN17**	**2**	**21**	**9**	**15**
26	**DN19**	**2**	**21**	**14**	**18**
27	**DN1F**	**2**	**21**	**11**	**17**
28	**DN56A**	**2**	**20**	**5**	**18**
29	**DN1A**	**1**	**10**	**1**	**9**
30	**DN24**	**1**	**20**	**11**	**18**
31	**DN2B**	**1**	**16**	**8**	**12**
32	**DN3A**	**1**	**10**	**2**	**8**
33	**DN3B**	**1**	**12**	**8**	**5**
34	**DN64**	**1**	**10**	**1**	**9**
35	**DN65A**	**1**	**14**	**5**	**12**
36	**DN66**	**1**	**11**	**6**	**6**
37	**DN68**	**1**	**10**	**8**	**5**
38	**DN69**	**1**	**10**	**6**	**5**
39	**DN73C**	**1**	**10**	**3**	**8**
	Total	**300**	**3351**	**1425**	**2625**

Distribution of accidents on DN1 depending on causes and counties									
i	**Cause i / County j**	**PH**	**CJ**	**BV**	**BH**	**IF**	**AB**	**SB**	**p_i**
1	Speed not adjusted to road	0.06	0.07	0.05	0.02	0.01	0.02	0.03	0.26
2	Jaywalking	0.04	0.02	0.01	0.02	0.02	0.01	0.01	0.12
3	Not giving priority to vehicles	0.03	0.01	0.01	0.01	0.00	0.01	0.00	0.08
4	Careless driving	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.08
5	Non-compliance with the pedestrian priority	0.03	0.02	0.00	0.01	0.02	0.00	0.00	0.07

6	Not paying attention when changing lane	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.06
7	Non-compliance with the distance between vehicles	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.07
8	Falling asleep at the steering wheel	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.04
9	Illegal overtaking	0.01	0.02	0.02	0.01	0.00	0.02	0.01	0.09
10	Driving under the influence of alcohool	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02
11	Cyclists' non-compliance with the traffic rules	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
12	Cart drivers	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
13	Illegal speed	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02
14	Children imprudence (aged 7-14)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
15	Driving on the wrong side of the road	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02
16	Other non-compliances with the traffic rules committed by drivers	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
17	Low experience in driving	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	Driving without a driver's license	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Pedestrians on the carriageway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
20	Non-compliance with the road signalling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Invalidity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Teenagers' imprudence (aged 14-18)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Not ensuring the stability of the load	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Non-compliance with the traffic-lights	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	Damaged road or men at work	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	Technical failures of vehicle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	Other causes related to road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p_i		**0.28**	**0.17**	**0.16**	**0.13**	**0.09**	**0.09**	**0.08**	**1.00**

Table 3.1

Source: UCAI [3]

For example, Fig. 3.2 shows that out of the 27 causes considered in table 3.2, about 10 causes are dominant in the occurrence of accidents on DN1. And Fig. 3.3 shows the county sectors with a high weight in the accidents location and therefore of the black spots location, which can be useful in the strategic orientation of the resources for preventing and treating the black spots according to the territorial criterion.

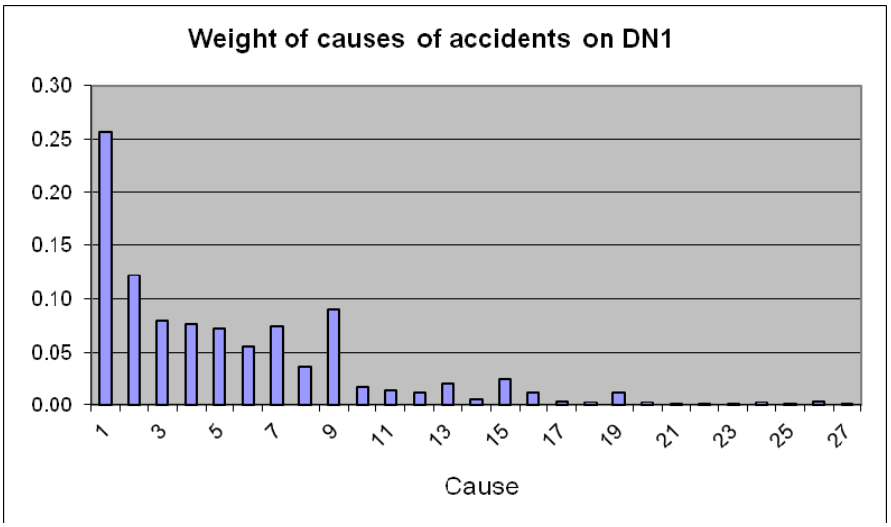

Fig. 3.2 Weight of causes of accidents on DN1

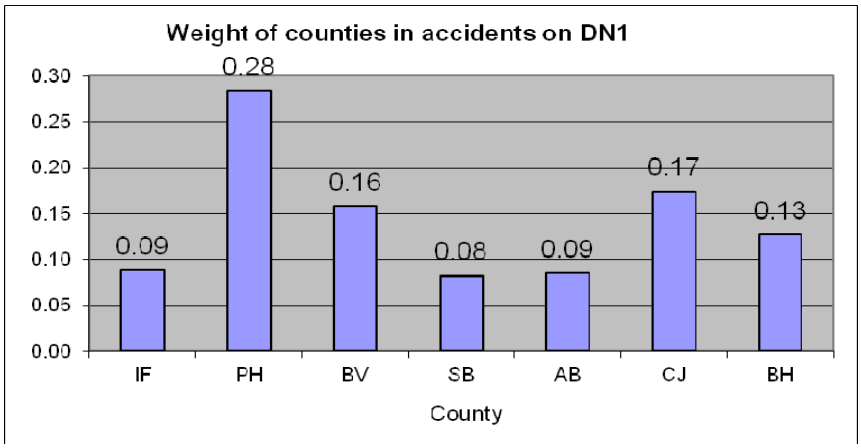

Fig. 3.3 Weight of counties in accidents on DN1

On the other hand, the complexity of the correlations between causes and the territorial sectors of DN1 is important where 29% of accidents happen in Prahova county, 14% of accidents are due to pedestrians, and over 27% to illegal or unadjusted speed.

The considered causes determine the accidents in all sectors, only the frequency of their incidence being different according to Fig. 3.4.

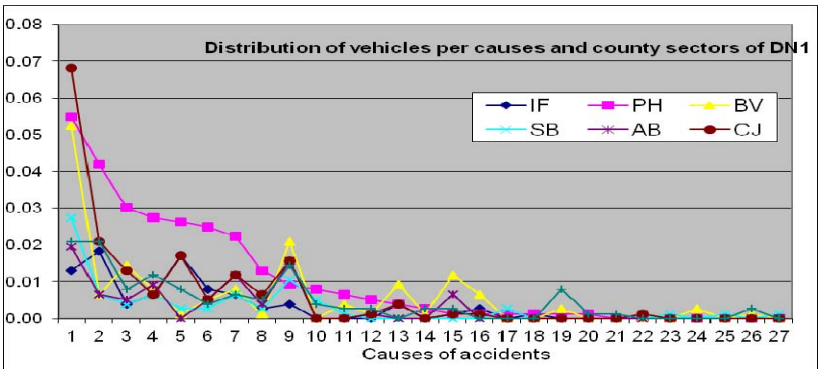

Fig. 3.4 Distribution of accidents per causes and county sectors of DN1

The time factor can determine the activation of some black spots. In the rest of the time, they are only a potential of danger for traffic safety.

The seasonal character of the accidents distribution on a certain road throughout the year, Fig. 3.5, as well as their distribution throughout the week or during the day, Fig. 3.6 belong to this category, according to data available at IGPR.

The correlations of the temporal variations of the accidents frequency are also very important. For example, there can be a correlation between the weekdays and the period during the day, which is a decisional support in the orientation of the operative resources for the prevention and abatement of the critical situations in traffic. For instance, for DN1, most of the accidents happen within the time interval 14.00 – 19.00, and the most fatal accidents happen in the second part of the week between 17.00 and 23.00, according to figure 3.6.

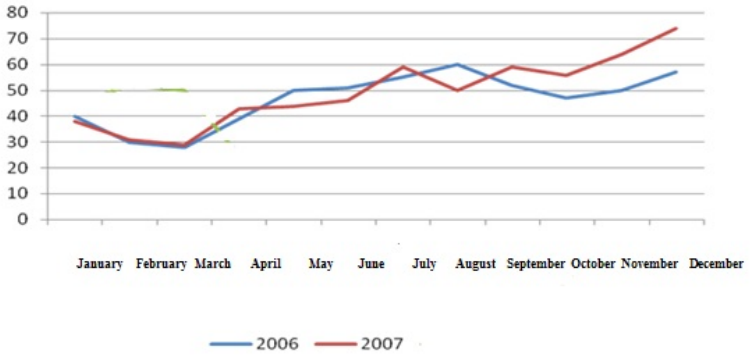

Fig.3.5 Seasonal yearly distribution of accidents on DN1

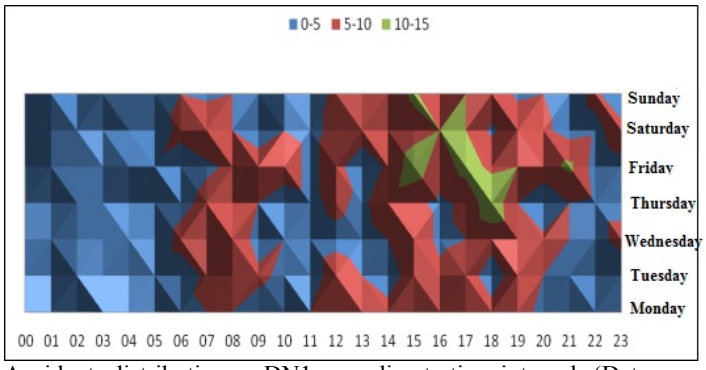

Fig.3.6 Accidents distribution on DN1 according to time intervals (Data source: IGPR)

3.3. Identification of the territorial patterns of the road risk along the road

The distribution of the road accidents and of the people killed on the county radius (according to data available at IGPR), depending on the milestone at which the accident happened is shown in figures 3.7-3.8 containing several graphs together with comments showing the main information provided by their form and content for DN1. Along the road corridor, it is noticed that the risk distribution is different from a county sector to another, following configurations characteristic of the respective road sectors.

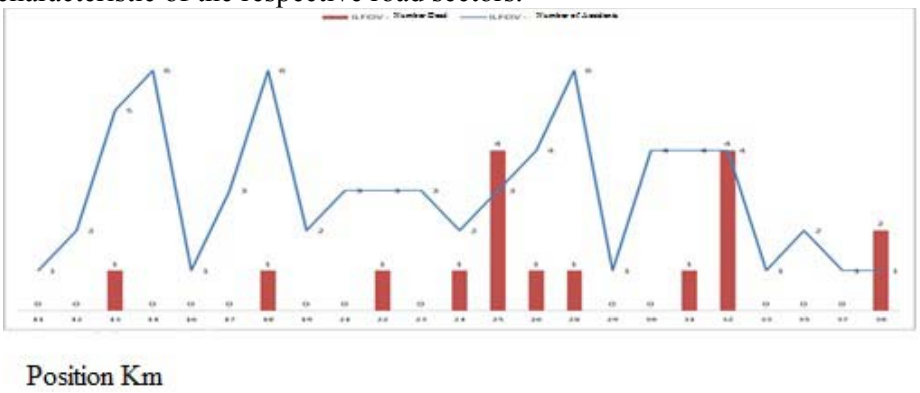

Fig.3.7 Road risk in Ilfov county (several critical points at km 14, 18, 28 and 30-32)

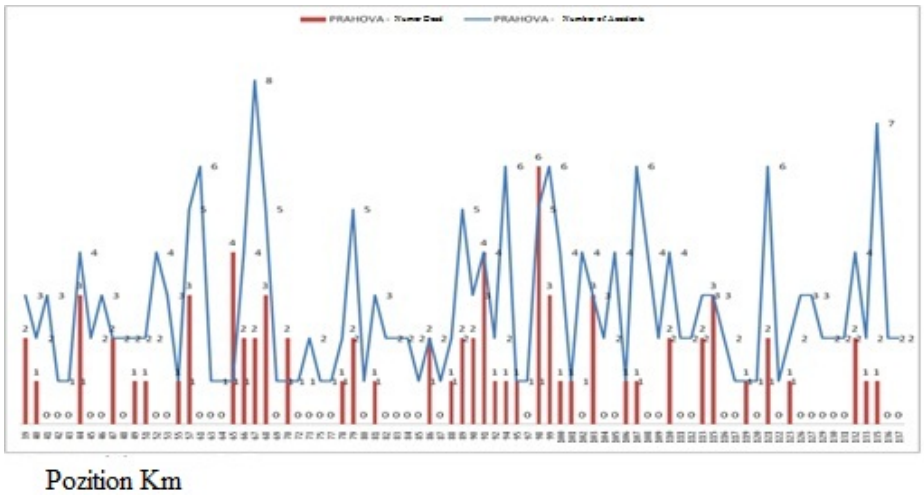

Fig.3.8 Road risk in Prahova county (many critical points and fatalities, some points congest in critical areas, critical county sector)

4. Category of factors contributing to the occurrence of road accidents

Most of the accidents occur due to the errors resulted from the inter-dependences between man, vehicle and road, which happen in the environmental context. To diminish the accident occurrence causes and their harmful effects, the relations within the man-vehicle-road system, which can be modelled, must be understood by using the modern trend for the application of the theory of categories in transports [4]. In this sense, the man-vehicle-road relation can be represented by the chart in figure 4.1, which commutes.

The morphisms represented by continuous lines shows how the influences in the man-vehicle-road system act, and those with dotted line show how the actions for improving the traffic safety and consequently for reducing the black spots propagate. The man-vehicle-road system is a complex system whose dynamics determines the traffic safety under certain environmental conditions.

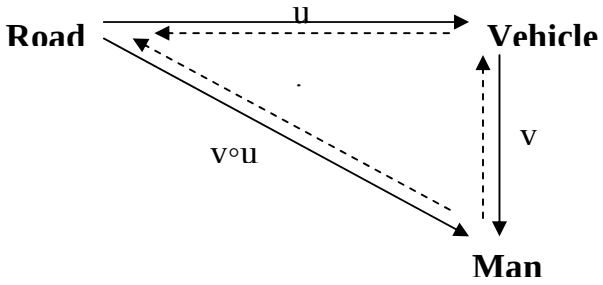

Fig. 4.1 A sequence in the category of influence factors of road safety

The environment should offer clear evidence regarding the rules and what the road users could expect [5]. This aspect is important, considering that there can be found roads with mixed, connection, distribution and communication functions between the strong or weak, heavy or light users travelling at high or low speed.

There are restoration measures that can be implemented to solve a part of the road safety issues related to environment/infrastructure [6].

On one hand, the driver is an item subjected to stress caused by driving their car and by the road (arrows with continuous line in figure 4.1), and on the other hand, the designers and constructors of the transport infrastructure and of the vehicles must follow the need to prevent the occurrence of car accidents (arrows with dotted line in Fig. 4.1).

As mentioned above, the road transport system is a category, having components (user, vehicle, road etc.) and relations between them, each of these factors being potential causes of the car accidents. More factors and the interactions between them are often responsible for a certain accident, and not a single factor.

These interactions are defined as: psychological and technical factors acting between vehicle and road; a man-vehicle interface between the user and the vehicle; human factor between user and road.

When data in the car accident statistics are not enough to elucidate the causes and processes resulting in the existence and even the consolidation of the black spots in a certain location or in a certain road sector, one can resort to the survey technique in order to identify the behavioural patterns of the participants in traffic. This procedure is more efficient, considering that the main cause of accident occurrence in Romania, especially the serious ones with people killed and injured, is represented by the drivers' behaviour in traffic. In 2007, 5701 of the 8415 (67.8%) of the serious accidents were caused by the car drivers. 1906 persons were killed (the total number of the people killed in car accidents being 2782) and 7640 persons (5141 of whom seriously) were injured because of the car drivers. With a view to increase the traffic safety degree and reduce the number of car accidents it is necessary to identify the causes, behaviours and attitudes promoting the infringement of the traffic rules by the car drivers and implicitly the accident occurrence. The method used is the questionnaire-based survey [7].

The behavioural study of the participants in the road traffic must identify:

- To what extent the traffic rules are observed by the drivers;
- Attitude of car drivers to the safety measures and traffic regulations;
- Social and cultural factors influencing the behaviour in traffic.

To exemplify the behavioural nuances that can be obtained by survey, in this paper is presented such a result showing the difference of perception of the risks of some attitudes and behaviours at drivers who have been involved in car

accidents over the last three years, as compared to those who have not been involved, table 4.1. Those involved in accidents state more frequently a risk behaviour in traffic, which shows that the experience of the accidents has not contributed significantly to the positive modification of the attitude in traffic, because a driving style, once internalized in the period of the car drivers' training, is no longer easy to modify by further experiences.

Table 4.1

Attitudinal categories of drivers in traffic			
no.	**Answer to questions**	**Involved in accidents**	
		Yes	**No**
1	Exceeding by 10-20 km/h the speed limit is acceptable because all the drivers do it	60	45
2	It's better to maintain a fluent traffic than to obey all the traffic rules	50.2	39.2
3	In order to arrive in time one can break some traffic rules	25	13.2
4	The congested traffic triggers bold manoeuvres	32	21
5	They like fast driving	33	22
6	They drove after having consumed alcoholic drinks	44.5	24.5
7	They never cross or rarely cross against a yellow light	57.4	75
8	They do not dangerously overtake	72.5	82.4
9	They do not get too close to the vehicle ahead	64.6	75
10	No aggressive behaviour against the other drivers	53.8	73.6
11	Agree with the tightening of the sanctions for speed exceeding	60.4	70.9

5. A new trend in approaching the transport safety policy

Although the social-economic and political background has radically changed in transports and logistic concepts, those - who elaborate the transport policy - are hardly adapting to changes, and are dependent on hereditary concepts coming from the past. If we also refer to the fact that the public institutions are not attractive for the specialists, it results how difficult is the problem of the human factor in transports safety policy.

The elaboration of transport safety policy must take into consideration the future goals which are going to be put in practice through on-line corrections following the strategies and measures results [8]. The complexity of transport safety systems and its interdependences with other systems makes necessary their institutionalization and on-line management as part of some transport policies which are continuously updated according to the achieved and anticipated phenomena and processes.

The institutionalized pattern of issuing and continuous implementation of the transports safety policy must accomplish the following conditions: to be

adaptive; to be able to be trained; to identify and process the simultaneous events; to be reliable and tolerant to mistakes; not to lose information no matter when and where it takes place; to identify the relevant information; to be flexible.

We can find an ideal solution to the institutional organization of the continuous actualization system of the transport safety policies, by realizing a neural network extend to the level of transport system.

Without entering into the neural network theory [9], we can name it as a way to fulfil all the above-mentioned conditions. The connection intensity of the neurons **i** and **j** is modified with the quantity:

$$\Delta w_{ij} = c.y_i.y_j \quad (1)$$

where **c** is the learning constant.

It thus results that the connection weights from the neuron **i** to the neuron **j** is modified at the time consecutive moment's **t** and **t + 1:**

$$w_{ij}\,(t+1) = w_{ij}\,(t) + \Delta w_{ij} \quad (2)$$

By connecting the neurons in networks any transport structure can be modelled. The neuron generates a signal **y** in the network if the signals received from upstream neuron raises the state **s** over a threshold value **h.** Through a special learning program which is further improved by own experience, the neural network will have a certain distribution of the values **w** and **h**.

As an intermediary stage towards an intelligent system of neural network type, the institutionalization of continuous actualization of the transport safety policy can be achieved by a simplified model located for example in a public institution.

6. Conclusions

The effectiveness of the ranked and integrated system for analysis and assistance of the decision-makers in the identification and treatment of the critical road safety situations has been validated as a result of the research and simulations conducted and experimented on the data available in official statistics. It has been noted that this approach provides the updating in due time of the system databases on the one hand, and helping information of strategic nature for decision-makers on various decisional levels on the other hand, which suggests the opportunity for continuing the improvement of the system in this direction.

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